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U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

ATTORNEY'S DOCKET NUMBER



TRANSMITTAL LETTER TO THE UNITED STATES  
DESIGNATED/ELECTED OFFICE (DO/EO/US)  
CONCERNING A FILING UNDER 35 U.S.C. 371

5077-000029

U.S. APPLICATION NO. (If known, see 37 CFR 1.5

09/807333

INTERNATIONAL APPLICATION NO.

INTERNATIONAL FILING DATE

PRIORITY DATE CLAIMED

PCT/JP00/07062

12 October 2000 (12.10.00)

12 October 1999 (12.10.99)

TITLE OF INVENTION MONITORING SYSTEM, CAMERA ADJUSTING METHOD AND VEHICLE  
MONITORING SYSTEM

APPLICANT(S) FOR DO/EO/US OKAMOTO, Shusaku, et al.

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below.
4. ☐ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
  - a. ☐ is attached hereto (required only if not communicated by the International Bureau).
  - b. ☒ has been communicated by the International Bureau.
  - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
  - a. ☒ is attached hereto.
  - b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
  - a. ☐ are attached hereto (required only if not communicated by the International Bureau).
  - b. ☐ have been communicated by the International Bureau.
  - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
  - d. ☒ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371 (c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11 to 20 below concern document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☐ A **FIRST** preliminary amendment.
14. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
15. ☐ A substitute specification.
16. ☐ A change of power of attorney and/or address letter.
17. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
18. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
19. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
20. ☒ Other items or information:

27 sheets of drawings showing Figs. 1-29C; copy of International Search Report, Form PTO-1449 and copies of references cited therein (1 JP), and this return postcard.

S0502495E2973

U.S. APPLICATION NO. (If none, use 37 CFR 1.53)

097807333

INTERNATIONAL APPLICATION NO.

PCT/JP00/07062

ATTORNEY'S DOCKET NUMBER

5077-000029

21. ☒ The following fees are submitted:**BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)):**

Neither international preliminary examination fee (37 CFR 1.482)  
 nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO  
 and International Search Report not prepared by the EPO or JPO ..... \$1000.00

International preliminary examination fee (37 CFR 1.482) not paid to  
 USPTO but International Search Report prepared by the EPO or JPO ..... \$860.00

International preliminary examination fee (37 CFR 1.482) not paid to USPTO  
 but international search fee (37 CFR 1.445(a)(2)) paid to USPTO ..... \$710.00

International preliminary examination fee (37 CFR 1.482) paid to USPTO  
 but all claims did not satisfy provisions of PCT Article 33(1)-(4) ..... \$690.00

International preliminary examination fee (37 CFR 1.482) paid to USPTO  
 and all claims satisfied provisions of PCT Article 33(1)-(4) ..... \$100.00

**ENTER APPROPRIATE BASIC FEE AMOUNT =****CALCULATIONS PTO USE ONLY**

\$ 860.00

Surcharge of \$130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30  
 months from the earliest claimed priority date (37 CFR 1.492(e)).

\$ 0.00

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE	
Total claims	12 -20 =	0	x \$18.00	\$ 0.00
Independent claims	7 -3 =	4	x \$80.00	\$ 320.00

**MULTIPLE DEPENDENT CLAIM(S)** (if applicable) **+ \$270.00**

\$ 0.00

**TOTAL OF ABOVE CALCULATIONS =**

\$ 1,180.00

☒ Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above  
 are reduced by 1/2.

\$ 0.00

**SUBTOTAL =**

\$ 1,180.00

Processing fee of \$130.00 for furnishing the English translation later than ☐ 20 ☐ 30  
 months from the earliest claimed priority date (37 CFR 1.492(f)).

\$ 0.00

**TOTAL NATIONAL FEE =**

\$ 1,180.00

Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be  
 accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property +

\$ 40.00

**TOTAL FEES ENCLOSED =**

\$ 1,220.00

Amount to be  
refunded: \$

charged: \$

- a. ☒ A check in the amount of \$ 1,220.00 to cover the above fees is enclosed.
- b. ☐ Please charge my Deposit Account No. \_\_\_\_\_ in the amount of \$ \_\_\_\_\_ to cover the above fees.  
 A duplicate copy of this sheet is enclosed.
- c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any  
 overpayment to Deposit Account No. 08-0750. A duplicate copy of this sheet is enclosed.
- d. ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card  
 information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

**NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR  
 1.137 (a) or (b)) must be filed and granted to restore the application to pending status.**

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NAME

28,764

REGISTRATION NUMBER

Dated: April 11, 2001

**DESCRIPTION****Monitoring System, Camera Adjusting Method  
and Vehicle Monitoring System****5 TECHNICAL FIELD**

The present invention relates to technique effective for a monitoring system using a camera, which technique is utilized as an aide of making sure of the safety, or the like when driving a vehicle.

**10 BACKGROUND ART**

There is conventionally known, as apparatus for actually capturing and monitoring the surrounding of a vehicle with the use of a camera, apparatus set forth in Japanese Patent Laid-Open Publication No. H3-99952. As shown in Fig. **15 29(a)**, this apparatus (vehicle surrounding situation monitor) is provided at the surrounding of a vehicle **100** with a plurality of vehicle surrounding situation monitoring cameras (**a ~ f**). This apparatus is arranged such that partial images captured by the respective cameras are converted in plan elevation to form partial images in plan elevation, and that these partial images are synthesized to form a whole image in plan elevation as shown in Fig. **20 29(b)**, and that this whole image is displayed on a display (TV monitor) **200**.

**25** In the apparatus above-mentioned, however, the road

monitoring cameras are not so arranged as to display even a rear scene. Accordingly, when intended to display a rear scene on the display at the time of backing operation, it is required to additionally dispose a rear monitoring camera g  
5 on the vehicle 100, in addition to the road capturing cameras above-mentioned.

#### DISCLOSURE OF INVENTION

It is an object of the present invention to provide a  
10 monitoring system used for a vehicle or the like, which is improved in camera mounting posture and position, thereby to improve the monitoring performance as compared with a conventional monitoring system.

More specifically, the present invention provides a  
15 monitoring system comprising a twin-camera composed of first and second cameras forming a pair, the first and second cameras being disposed such that at least portions of the ranges to be captured thereby overlap each other, and that the optical axes thereof form a predetermined angle of divergence  
20 when the optical axes are projected on a camera installation plane parallel to the optical axes, and the twist around the optical axis of at least one of the first and second cameras being set such that when a u-v plane of the visual field range of the at least one camera is projected on a reference  
25 plane at a right angle to the optical axis of the at least

one camera, the u axis is not parallel to and does not intersect, at a right angle, the intersecting line of the reference plane and the camera installation plane.

The twin-camera is preferably mounted on a vehicle for capturing both the surrounding of the vehicle and a place distant therefrom. Further, the twin-camera is preferably disposed such that the angle of divergence is not less than  $50^{\circ}$  and not greater than  $90^{\circ}$ , and that the twist is not less than  $10^{\circ}$  and not greater than  $35^{\circ}$  on the assumption that the twist is  $0^{\circ}$  when the u axis on the reference plane is parallel to the intersecting line of the reference plane and the camera installation plane.

Preferably, each of the first and second cameras has a visual field range in the form of a square.

The present invention provides a method of adjusting a twin-camera composed of a pair of cameras mounted on a vehicle for capturing both the surrounding of the vehicle and a place distant therefrom, this camera adjusting method being characterized in that the tilt, pan and twist around the optical axis of each of the pair of cameras, are adjusted using, as indexes, the length of a portion, as captured by each camera, of the straight line indicating the capturing direction, the length of a portion, as captured by each camera, of a straight line extending along the vehicle end, and the area of the blind zone in the capturing direction.

The present invention provides a vehicle monitoring system comprising: a plurality of cameras for capturing the surrounding of a vehicle; and an image processing unit for generating, from the images captured by the plurality of cameras, a synthesized image viewed from a virtual view point, the plurality of cameras comprising a twin-camera composed of two cameras which form a pair and which are disposed in the close vicinity to each other.

The twin-camera is preferably mounted in a unitary structure.

The present invention provides a vehicle monitoring system comprising: one or a plurality of cameras for capturing the surrounding of a vehicle; and an image processing unit for generating, from the images captured by the one or plurality of cameras, a synthesized image viewed from a virtual view point, at least one of the one or plurality of cameras being mounted on the vehicle at its lateral side, a non-movable part of its door mirror, its window visor or its door knob mounting part.

The present invention provides a vehicle monitoring system comprising: one or a plurality of cameras for capturing the surrounding of a vehicle; and an image processing unit for generating, from the images captured by the one or plurality of cameras, a synthesized image viewed from a virtual view point, at least one of the one or plurality of cam-

eras being disposed as corresponding to illumination means for irradiating light to the range to be captured by the at least one camera.

The present invention provides a vehicle monitoring system comprising: one or a plurality of cameras for capturing the surrounding of a vehicle; and an image processing unit for generating, from the images captured by the one or plurality of cameras, a synthesized image viewed from a virtual view point, at least one of the one or plurality of cameras being so retractably mounted on the vehicle as to be ejected when the camera is used, and as to be housed when the camera is not used.

The retractable camera is preferably arranged such that its ejecting and housing is controlled according to at least one of the gear setting or travelling speed of the vehicle.

The present invention provides a vehicle monitoring system comprising: one or a plurality of cameras for capturing the surrounding of a vehicle; and an image processing unit for generating, from the images captured by the one or plurality of cameras, a synthesized image viewed from a virtual view point, at least one of the one or plurality of cameras being mounted on the vehicle together with an openable member disposed at the front in the capturing direction of the at least one camera, the openable member being so controlled as to be opened when the camera is used, and as to be

closed when the camera is not used.

#### BRIEF DESCRIPTION OF DRAWINGS

Fig. 1(a) and Fig. 1(b) are views respectively illustrating the arrangements of vehicle monitoring systems according to embodiments of the present invention;

Fig. 2 is a view for illustrating a conversion table used in each of the vehicle monitoring systems in Fig. 1;

Fig. 3 is a view illustrating how a rear monitoring camera is mounted in prior art;

Fig. 4 is a view illustrating how a twin-camera according to a first embodiment of the present invention is mounted;

Fig. 5 is a view illustrating the relationship between the tilt, pan and twist representing the camera direction, and the XYZ axes of the coordinates system which defines the space;

Fig. 6(a) to Fig. 6(c) are views illustrating the rotating operations to be conducted for determining the tilt, pan and twist representing the camera direction;

Fig. 7 shows an example of the ranges to be captured and the images captured when the twin-camera shown in Fig. 4 is mounted on the vehicle rear trunk;

Fig. 8 is a view illustrating a world coordinates system used when mounting the camera;



Fig. 9 shows views for illustrating an evaluation value according to the first embodiment of the present invention;

Fig. 10(a) to Fig. 10(c) are views illustrating examples of calculation results of evaluation value;

5 Fig. 11(a) and Fig. 11(b) are conceptual views illustrating how the visual field range is changed according to the rotation of the camera around its optical axis;

Fig. 12(a) and Fig. 12(b) are views illustrating virtual visual point images obtained at the time when the twist  
10 is  $0^\circ$  as shown in Fig. 11(a);

Fig. 13(a) and Fig. 13(b) are views illustrating virtual visual point images obtained at the time when the twist  
15 is  $33.2^\circ$  as shown in Fig. 11(b);

Each of Fig. 14(a) and Fig. 14(b) is a view illustrating a virtual visual point image, as viewed from above, which  
15 is obtained by synthesizing the images captured by the twin-camera;

Fig. 15(a) and Fig. 15(b) are views of a vehicle and its surrounding for illustrating second and third embodiments  
20 of the present invention, in which Fig. 15(a) is a plan view and Fig. 15(b) is a side view;

Fig. 16(a) and Fig. 16(b) are views illustrating images captured by the respective cameras shown in Fig. 15;

Fig. 17 is a virtual visual point image formed with the  
25 use of the captured images in Fig. 16;

Fig. 18(a) and Fig. 18(b) are views for illustrating the third embodiment of the present invention, and show the images captured by the respective cameras shown in Fig. 15;

Fig. 19 is a virtual visual point image formed with the use of the captured images in Fig. 18;

Fig. 20(a) and Fig. 20(b) are views illustrating the third embodiment of the present invention in which three cameras are mounted;

Fig. 21 is a plan view of a vehicle and its surrounding according to a fourth embodiment of the present invention;

Fig. 22(a) to Fig. 22(d) are views illustrating the images captured by the respective cameras shown in Fig. 21;

Fig. 23 is a virtual visual point image formed with the use of the captured images in Fig. 22;

Fig. 24 is a plan view of a vehicle and its surrounding according to a fifth embodiment of the present invention;

Fig. 25(a) to Fig. 25(d) are views illustrating the images captured by the respective cameras shown in Fig. 24;

Fig. 26 is a virtual visual point image formed from the captured images in Fig. 25;

Fig. 27(a) and Fig. 27(b) show an example of how a camera is mounted according to a sixth embodiment of the present invention, in which a retractable mode is adopted;

Fig. 28(a) to Fig. 28(e) show another examples of how the camera is mounted according to the sixth embodiment of

the present invention, in which an opening/closing mechanism is adopted; and

Fig. 29(a) to Fig. 29(c) are views for illustrating technique of prior art.

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#### BEST MODE FOR CARRYING OUT THE INVENTION

The following description will discuss embodiments of the present invention with reference to the attached drawings.

Fig. 1(a) and Fig. 1(b) are functional block diagrams of vehicle outside display apparatus, serving as vehicle monitoring systems, according to embodiments of the present invention. In Fig. 1(a), the vehicle outside display apparatus 10 comprises: a plurality of color CCD cameras C1 ~ Cn serving as capturing means to be mounted on a plurality of positions of a vehicle; an image processing device 11 which receives captured images TP1 ~ TPn from the cameras C1 ~ Cn, and which processes and supplies these captured images TP1 ~ TPn as virtual visual point image data PP\_D; and a liquid-crystal display 12 which receives the data PP\_D and displays a virtual visual point image PP. The image processing device 11 executes processings on the captured images TP1 ~ TPn with the use of any of conversion tables TBL1 ~ TBLm.

Typically, the capturing means is a color or monochrome digital camera having a solid-state pickup element such as a CCD, CMOS device or the like. The capturing means may be

formed for example by a combination of a lens and a prism or a mirror, and may be arranged such that light incident upon the lens, the prism or the mirror passes through a predetermined optical passage and is transmitted to a pickup element  
5 disposed at a position remote from the capturing means.

The camera may have two or more mounting postures (such that the camera direction can be changed), or may be arranged such that the range to be captured is changed by a zooming operation or the like. It is a matter of fact that when the  
10 camera is changed in mounting posture and the range to be captured, the image processing device 11 suitably executes a different processing.

The image processing device 11 may be mounted on the vehicle or may be disposed at a place other than the vehicle.  
15 In the latter case, the image data from the capturing means are transmitted in a wireless manner to an image processing device outside of the vehicle, and this image processing device executes a predetermined processing on the received image data to form a virtual visual point image, and sends this  
20 virtual visual point image thus formed to the display mounted on the vehicle.

Typically, the display is a liquid-crystal display, but may be other display device such as a plasma display or the like. The display may also serve as a vehicle-mounted GPS  
25 terminal display (a display of a so-called car navigation

system), or may be disposed independently therefrom.

The display mode of the vehicle outside display apparatus 10, is determined according to the conversion table used by the image processing device 11. The display mode may be switched manually or automatically. Examples of the processing to be executed by the image processing device 11, include ① a clipping processing, ② an image deforming processing, and ③ a processing of synthesizing the clipped partial images (including a boundary processing).

The term "clipping" means cutting, from the captured image, a part required for synthesizing a virtual visual point image. The term "boundary processing" means a processing of hiding the boundary between adjacent partial images or a processing of causing the boundary between adjacent partial images to be not noticeable. More specifically, to hide or cause the boundary between adjacent partial images to be not noticeable, the adjacent partial images may be, for example, partially put one upon another at the boundary portions thereof, and there may be used a method of smoothing the change in at least one of brightness, chroma and hue of the overlapping portions at the boundary. It is a matter of course that the boundary between adjacent partial images may be marked clearly by a division line.

These processings ① - ③ may be executed respectively individually, or the whole or a portion of these processings

①-③ may be executed at one step. The clipping and synthesizing processings may be executed after the deforming processing has been executed on the captured images, or the deforming and synthesizing processings may be executed after the clipping processing has been executed. For example, when the pickup element is a CCD, the clipping processing can be executed after the captured image has been taken into a frame buffer. When the pickup element is a CMOS device, a portion to be clipped can be designated at the time of capturing, and the clipped image can be taken into the frame buffer.

The display 12 displays a vehicle figure M formed by computer graphics. This vehicle figure M represents a vehicle image viewed from the virtual visual point. However, the display 12 does not always display the vehicle figure M viewed from the virtual visual point.

Fig. 2 is a view illustrating an example of the conversion table. Fig. 2 shows the relationships between the pixel coordinates (i, j) of the virtual visual point image PP and the mapping data.

More specifically, the conversion table is used for converting the pixel coordinates of a partial image into the pixel coordinates of the virtual visual point image. Depending on the position of the virtual visual point, the camera mounting position and the like, the pixel coordinates of a partial image correspond to the pixel coordinates of the vir-

tual visual point image on the basis of 1:1 or a plural number:1. For example, when the boundary processing is executed on the boundary between partial images, the pixel coordinates of a partial image do not always correspond to the pixel coordinates of the virtual visual point image on the basis of 1:1.

In Fig. 2, the coordinates (i1, j1) represent the pixel to which the partial image captured by a camera Cp (p is any of 1 ~ n) corresponds, and there are prepared, as the mapping data corresponding to this pixel, the XY coordinates in the partial image captured by the camera Cp. The coordinates (i2, j2) represent the pixel which is equivalent to the boundary at which the partial image captured by the camera Cp overlaps the partial image captured by a camera Cq (q is any of 1 ~ n except p), and there are prepared, as the mapping data, the XY coordinates and the necessity degree of the partial images captured by the cameras Cp and Cq. In such a case, the pixel value of the coordinates (i2, j2) can be expressed for example in the following manner:

$$\text{Pixel value} = \{(\text{pixel value of the coordinates (56,80) of the camera Cp}) \times 0.5 + (\text{pixel value of the coordinates (10,10) of the camera Cq}) \times 0.3\} / (0.5 + 0.3)$$

Fig. 1(b) shows the arrangement in which the conversion tables TBL1 ~ TBLm are disposed in an image processing de-

vice 11A. A processor (not shown) in the image processing device 11A refers to any of the conversion tables TBL1 ~ TBLm.

More specifically, the conversion tables TBL1 ~ TBLm shown in Fig. 1 are being written in a ROM (including a writing and erasable ROM such as an EEPROM or the like) or a RAM. The conversion tables may be generated by a processor in the image processing device 11 which calculates conversion table data and writes the data thus calculated in the RAM or ROM.

Alternatively, the conversion tables may be generated by writing the conversion table data supplied as firmware in the RAM or ROM with the use of data transmission means such as a communication circuit, a disk drive or the like.

As to each of the images captured by the cameras C1 ~ Cn, it is possible to previously set the range to be clipped and to previously determine this range to be clipped based on the clipping reference point.

The function of the image processing device may wholly or partially be achieved with the use of a dedicated hardware or software. It is also possible to utilize a recording medium or transmission medium which stores a program for causing the computer to execute the whole or partial function of the image processing device.

The following description will discuss embodiments of the present invention. For convenience's sake, each camera,



the human body and the like are shown in illustration although these should originally be shown in photograph.

(First Embodiment)

5           Fig. 3 is a view illustrating how a rear monitoring camera is mounted in prior art. To monitor in more detail the vehicle in the rear direction, it is desired to capture a range as broad as possible from the vicinity just behind the vehicle to a place distant therefrom. In this connection, a  
10 camera having a very wide visual field of which field of view exceeds  $110^\circ$ , is recently increasingly used as capturing means for monitoring the vehicle in the rear direction. As shown in Fig. 3, however, even with a wide-angle camera, blind zones D deviating from the range to be captured are inevitably generated at both sides just behind a vehicle 21 as  
15 far as the field of view of the camera is smaller than  $180^\circ$ . Particularly, when those portions DS of the blind zones D located at inner parts with respect to the vehicle width, cannot be seen, an object present in the portions DS cannot be  
20 recognized on the captured image. This introduces the danger of causing trouble in view of safety when the vehicle travels in the backward.

To solve the problem above-mentioned, there is generally proposed a method of using, as the capturing means, a  
25 camera using a lens, for example a fisheye lens, having an

ultra wide visual field of  $180^\circ$  or more. However, this method is disadvantageous in that the cost is increased because the precision required for lens machining is very high, and that a fine resolution cannot be obtained because the range to be captured is too wide. Thus, this method is encountered by many problems before being put into practical use. Accordingly, as compared with the use of an ultra-wide visual field camera, it is considered more effective in view of cost and resolution to use a pair of two cameras in order to obtain a visual field of  $180^\circ$  in the left and right directions.

Fig. 4 is a conceptual view illustrating a mode of mounting, as a pair, two cameras 23L, 23R in close vicinity to each other. Fig. 4 shows an example of arrangement in which the two cameras 23L, 23R serving as a twin-camera 23 are disposed such that a visual field of  $180^\circ$  is obtained, that the two cameras 23L, 23R are as close to each other as possible, and that the optical axes thereof intersect each other. In this specification, the term "twin-camera" means a pair of two cameras disposed in close vicinity to each other.

When mounting, on a vehicle, the cameras having the arrangement above-mentioned, it is very important in which directions the cameras forming a pair are disposed.

When only one camera is mounted as a rearward monitoring capturing means as conventionally done, the camera can be

situated substantially in the optimum position by a simple method of first turning the camera just in the rear direction of the vehicle and adjusting the tilt thereof according to the application. More specifically, when a single camera is  
5 used, the adjustment is simple because it is enough to determine only the tilt of the camera.

In a twin-camera, the adjustment of the cameras forming the twin-camera is complicated as compared with a single camera. More specifically, it is not required to independently  
10 adjust the postures of the respective cameras forming the twin-camera, but it is required to adjust the optimum postures of the respective cameras while making sure of both the range to be captured by one camera and the range to be captured by the other camera. Making sure of the ranges to be  
15 captured by the two cameras, means, for example, making sure that the range to be captured by one camera does not overlap too much the range to be captured by the other camera, and making sure that there is no place which is not captured by either camera.

20 This embodiment discloses a method of setting the postures of the respective cameras forming the twin-camera as shown in Fig. 4.

First, the camera direction is to be defined. It is a common practice to determine a camera direction by combining  
25 the rotations around the X axis, Y axis and Z axis of the

space defining coordinates system as shown in Fig. 5. In this specification, the rotations around the X, Y and Z axes are respectively called tilt, pan, and twist. Clockwise rotation of each axis is represented by a positive angle, while  
5 counterclockwise rotation of each axis is represented by a negative angle. The camera direction obtained by conducting the rotating operations shown in Fig. 6(a), Fig. 6(b), Fig. 6(c) in this order, is represented in the form of tilt, pan, and twist.

10 By these three kinds of angles(tilt, pan, twist), the camera direction in the coordinate system can be uniquely determined. In other words, to optimize each camera direction in a twin-camera, it is required to adjust, in addition to the tilt, two other angles, i.e., the pan and the twist,  
15 unlike in the adjustment of a single camera.

Fig. 7 shows an example of the ranges to be captured and the images captured when the twin-camera 23 shown in Fig. 4 is mounted on the vehicle rear trunk.

The conditions for capturing a possibly broad range  
20 from the surrounding just behind the vehicle to a place distant therefrom in order to monitor the vehicle in the rear direction, are described in the following three items when qualitatively expressed with the use of the images of the two cameras 23L, 23R:

25 1. The vehicle center line BCL should be seen in the

rear direction as far as possible (up to the horizon if possible).

2. The vehicle rear-end line **BEL** should be seen in the vehicle transverse directions as far as possible (up to the horizon if possible).

3. The blind zone **S** behind the vehicle should be minimized.

The item 1 is the condition for assuring the visual field just behind the vehicle. Particularly, when the cameras are disposed in the form of a twin-camera, the center line **BCL** must overlappingly be captured by each of the two cameras **23L**, **23R**. Otherwise, when the respective rear images are synthesized, there is formed a blank at the rear center part of the synthesized image, introducing a serious problem in view of safety. It is therefore desired that the center line **BCL** is seen as far away as possible by each of the two cameras **23L**, **23R**. The item 2 is the condition for assuring the visual field just beside the vehicle, and the item 3 is the condition for assuring the visual field just below and just behind the vehicle.

Accordingly, when it is possible to calculate the degree at which each of the three conditions above-mentioned is satisfied, the camera direction can efficiently be determined.

In this connection, to numerically evaluate the three condition items above-mentioned, a world coordinates system

as shown in Fig. 8 is introduced. In this coordinates system, the respective axes are defined as set forth below:

X-axis: the line, as projected on the road surface, of the boundary between the road surface viewed by a camera and the vehicle bumper, on the assumption that the bumper is linear.

Y-axis: the vehicle longitudinal center line on the road surface

Z-axis: the line which is perpendicular to the road surface and which passes through the intersecting point of the X and Y axes.

In the coordinates system thus defined, the three items above-mentioned can quantitatively be evaluated with the use of the following indexes:

1. The distance from the origin point to the remotest rear point which can be seen. In Fig. 9, this distance corresponds to the length of a portion **P0-P1**, as captured by a camera, of the vehicle center line **BCL**.

2. The distance from the origin point to the remotest transverse point which can be seen. In Fig. 9, this distance corresponds to the length of a portion **P0-P2**, as captured by a camera, of the vehicle rear-end line **BEL**.

3. The area of the blind zone **S** just behind the vehicle.

Accordingly, each camera direction may be determined such that 1. the length **P0-P1** is as long as possible, 2. the

length **P0-P2** is as long as possible, and 3. *S* is minimized when quantitatively expressing the three condition items mentioned earlier. To evaluate the three items collectively, the following evaluation value is for example introduced:

$$\text{Length } \mathbf{P0-P1} \times \text{Length } \mathbf{P0-P2} \times 1/S$$

When **P1**, **P2** are positioned on the horizon, the length **P0-P1** and the length **P0-P2** are infinite. Accordingly, sufficiently large values are previously determined as the upper limits of the length **P0-P1** and the length **P0-P2**.

When mounting the cameras on the vehicle, it is supposed that the camera mounting position has substantially no degree of freedom with the vehicle body design taken into consideration. Accordingly, at a predetermined mounting position, the evaluation value above-mentioned may be evaluated only according to the camera direction (tilt, pan, twist) shown in Figs. 5 and 6. More specifically, while mutually independently changing the three kinds of angles forming the camera direction, i.e., the tilt, pan, and twist around the optical axis, the evaluation values are calculated, and based on the evaluation values thus calculated, the optimum camera direction (tilt, pan, twist) can be obtained.

Fig. 10 is an example of the calculation results of evaluation values. In Fig. 10, it is supposed that a camera having a field of view of  $110^\circ$  is mounted, in the world coordinates system in Fig. 7, at a position of the coordinates (3 cm, 20 cm, -1 m), i.e., 3 cm in the positive

cm, 20 cm, -1 m), i.e., 3 cm in the positive direction of the X axis from the origin 0, 20 cm in the positive direction of the Y axis and 1 m in the negative direction of the Z axis (1 m in height). Fig. 10 shows the results of the evaluation values calculated with respect to three different tilts while the pan is changed from  $5^\circ$  to  $45^\circ$  and the twist around the camera optical axis is changed from  $-30^\circ$  to  $30^\circ$ .

From the test results including the example in Fig. 10, it is understood that a high evaluation value is obtained in the range of the pan from about  $25^\circ$  ~ about  $45^\circ$  and in the range of the twist from about  $-35^\circ$  - about  $-10^\circ$ . According to the tests conducted by the Inventor of this application, it is found that the highest evaluation value is obtained with the tilt of about  $40^\circ$ .

A plane parallel to the optical axes of the two cameras 23L, 23R is defined as a camera installation plane. There is also defined, as an angle of divergence, the angle formed by the optical axes of the two cameras 23L, 23R at the time when the cameras 23L, 23R are projected on this camera installation plane. The angle of divergence corresponds to an angle twice the pan above-mentioned. More specifically, the angle of divergence is preferably in the range not less than  $50^\circ$  and not greater than  $90^\circ$ .

A plane at a right angle to the optical axis of a cam-



era is defined as a reference plane. Then, there is considered the relationship between the u axis of a u-v plane of the camera visual field range at the time when the u-v plane is projected on the reference plane, and the intersecting line of the reference plane and the camera installation plane. When the twist is not adjusted, i.e., when the twist is  $0^\circ$ , the projected u axis is parallel to the intersecting line of the reference plane and the camera installation plane.

More specifically, in a twin-camera, the twist around the optical axis of each camera is preferably set such that the u axis projected on the reference plane and the intersecting line of the reference plane and the camera installation plane, are not parallel to each other but intersect each other at a certain angle. Dependent on how to define the u-v coordinates of the camera visual field range, there are instances where the projected u axis intersects, at a right angle, the intersecting line of the reference plane and the camera installation plane, even though the twist is equal to  $0^\circ$ . Accordingly, strictly speaking, the twist around the optical axis of each camera is preferably set such that the u axis projected on the reference plane is not parallel to and does not intersect, at a right angle, the intersecting line of the reference plane and the camera installation plane.

Further, the results above-mentioned show that a high evaluation value is obtained in the range of the twist from -

35° ~ -10° for one camera and from 10° ~ 35° for the other camera. This means that the twin-camera is preferably set such that the projected u axis and the intersecting line of the reference plane and the camera installation plane, intersect each other at an angle in the range not less than 10° and not greater than 35° .

According to this embodiment, the camera direction is determined with the use of the evaluation value above-mentioned, but this evaluation value may be changed by other standard according to the object. For example, when it is enough to see only the close vicinity just behind the vehicle in the rear direction, the importance of the condition 1 is lowered. In such a case, the weight of "the length **P0-P1**" in the evaluation value may be reduced.

In the foregoing, the description has been made of how to determine the posture of a camera for monitoring the vehicle in a rear direction. However, the posture of a camera for monitoring the vehicle in a transverse direction or in a front direction, can also be determined by a similar method. More specifically, a straight line indicating the capturing direction may be supposed instead of the vehicle center line **BCL**, and a straight line extending along the vehicle end may be supposed instead of the vehicle rear-end line **BEL**. Then, by evaluating data in a manner similar to that in the embodiment above-mentioned, a suitable camera direction may be de-

terminated.

In adjustment of the posture of a twin-camera, setting of the twist around the optical axis of each camera is very important. The following will discuss the result of study of the Inventor on the reason of why such setting is important.

Fig. 11(a) and Fig. 11(b) are conceptual views illustrating how the visual field range is changed according to the rotation of the camera around its optical axis. Fig. 11(a) shows the case where the twist is  $0^\circ$  (no rotation around the optical axis), while Fig. 11(b) shows the case where the twist is  $33.2^\circ$ . In Fig. 11, one camera 23L of the twin-camera is shown. The camera 23L has a field of view of  $111^\circ$  and is positioned at the coordinates (3 cm, 10 cm, -1 m) with the tilt set to  $40^\circ$  and the pan set to  $30^\circ$ .

Now comparison is made between Fig. 11(a) and Fig. 11(b). In Fig. 11(a), the camera can see only 11 m in the transverse direction at the vehicle rear end (vehicle rear-end line BEL) and only 4.4 m just in the rear direction at the vehicle longitudinal center (vehicle center line BCL). On the other hand, in Fig. 11(b), the camera can see a place which reaches the horizon HL in each of the transverse direction at the vehicle rear end and the rear direction at the vehicle longitudinal center. It is understood that the visual field can considerably be enlarged only by changing the twist even though other conditions than the twist are the

same. It is considered that such change is caused due to the fact that the camera visual field range is square. The difference in visual field range results in a greater difference when a virtual visual point image is synthesized.

5 Fig. 12(a) and Fig. 12(b) are views illustrating the virtual visual point images obtained at the time when the twist is  $0^\circ$  as shown in Fig. 11(a), and Fig. 13(a) and Fig. 13(b) are views illustrating the virtual visual point images obtained at the time when the twist is  $33.2^\circ$  as shown in Fig. 11(b). As shown in Fig. 12, only the range of 4.4 m from the vehicle just behind the same, is captured by the camera when its twist is  $0^\circ$ . Accordingly, a person standing at a position, in the vehicle rear direction, remote by more than 4.4 m from the vehicle, does not appear at all on the virtual visual point image. On the contrary, when the twist is 15  $33.2^\circ$ , the rear scene just behind the vehicle is reflected on the camera up to the horizon HL as shown in Fig. 13. Accordingly, a person standing at a position of about 5 m from the vehicle in the rear direction, can securely be reflected 20 on the virtual visual point image.

As discussed in the foregoing, the range of the visual field is considerably changed by adjusting the twist around the optical axis of the camera. This considerably changes the range of the vehicle surrounding to be displayed as a 25 virtual visual point image. More specifically, to properly

set the twist around the optical axis of each camera, is very important in a twin-camera for determining the performance of the monitoring system.

In a twin-camera, two cameras forming a pair are disposed in close vicinity to each other. The distance between the cameras is preferably as small as possible.

Fig. 14(a) and Fig. 14(b) are views illustrating virtual visual point images, as viewed from above, which are obtained by synthesizing the images captured by the twin-camera.

Fig. 14(a) shows the case where the two cameras 23L, 23R are disposed in close vicinity to each other, while Fig. 14(b) shows the case where the two cameras 23L, 23R are disposed with a small distance provided therebetween. Shown in Fig. 14 are an area VAL where only the image of the camera 23L is used, an area VAR where only the image of the camera 23R is used, an area VAB where the images of the two cameras 23L, 23R are synthesized, a pole P just behind the vehicle, an image PIL which is the image of the pole P synthesized from the image of the camera 23L, and an image PIR which is the image of the pole P synthesized from the image of the camera 23R.

Fig. 14(a) and Fig. 14(b) are different from each other in that the pole P is included or not included in the area VAB in the synthesized image. More specifically, in Fig. 14(a), the pole images PIL, PIR respectively captured by the two cameras 23L, 23R are included in the area VAB. On the

other hand, in Fig. 14(b), the two cameras 23L, 23R are disposed as slightly separated from each other and therefore, the pole images PIL, PIR protrude from the area VAB in the synthesized image. As a result, only the base portion of the pole P is shown in the synthesized image, causing the image at the boundary to be unnatural.

From the study of the Inventor, it has been found that, when partial images are synthesized at the time the distance between the image forming points of the camera lenses is 20 cm or more, a shear in image at the boundary is increased, readily causing the image at the boundary to be unnatural. More specifically, when disposing a twin-camera, it is preferable to dispose the two cameras such that the image forming points thereof are not separated from each other by 20 cm or more. Further, the two cameras forming a twin-camera are preferably packaged in a unitary structure.

This embodiment can be applied not only to a vehicle monitoring system, but also to a monitoring system for other application. More specifically, the technical concept of this embodiment can readily be applied to any system as far as the system has a twin-camera composed of cameras forming a pair.

#### (Second Embodiment)

According to a second embodiment, it is supposed that

the display mode of the vehicle outside display apparatus 10 shown in Fig. 1 is set to a rear wide visual field scene display mode.

Fig. 15(a) and Fig. 15(b) are views of a vehicle 1 and its surrounding. That is, Fig. 15(a) is a plan view and Fig. 15(b) is a side view. Shown in Fig. 15 are a front window **Front\_w** of the vehicle 1, a rear bumper **Rear\_Bp**, a trunk **Tr** and white lines **3A**, **3B**, **3C** drawn on the ground surface. A pedestrian 2 (infant) stands behind the vehicle 1.

As shown in Fig. 15, two cameras **C1**, **C2** forming a pair are disposed in close vicinity to each other at the rear part of the vehicle 1, the two cameras **C1**, **C2** being turned slightly obliquely downward and rearwardly outward. There are also shown a range to be captured **RC1** by the camera **C1** and a range to be captured **RC2** by the camera **C2**. A straight line **L1** divides, into two equal portions, the overlapping portions of the ranges to be captured **RC1**, **RC2** of the cameras **C1**, **C2**, and a straight line **Lh** is horizontally drawn from the mounting position of the cameras **C1**, **C2**.

As understood from Fig. 15(b), the cameras **C1**, **C2** are disposed such that each of the ranges to be captured by the cameras **C1**, **C2** includes both a portion of the rear bumper **Rear\_Bp** and a portion of the horizon which would be seen when it is supposed that the vehicle is present on a level ground where no obstacle exists.

Fig. 16(a) shows the image TP1 captured by the camera C1 and Fig. 16(b) shows the image TP2 captured by the camera C2. There are also shown clipping ranges RGN\_01, RGN\_02. As shown in Fig. 16, provision is made such that each of the  
5 clipping ranges RGN\_01, RGN\_02 includes the rear bumper Rear\_Bp.

Fig. 17 shows a virtual visual point image PP\_1 displayed on the display 12. In the image in Fig. 17, the virtual visual point is set such that the rear visual field is spread in a wide area in the vicinity of the trunk Tr of the vehicle 1.  
10

According to the second embodiment, the image processing device 11 executes simultaneously a processing of preparing partial images by clipping the captured images TP1, TP2 while referring to the conversion table TBL1 (table for a rear scene display), a processing of deforming the partial images to a virtual visual point image PP\_1, and a processing of synthesizing the partial images (including a boundary processing). Accordingly, the virtual visual point image  
15 PP\_1 as shown in Fig. 17 is displayed on the display 12.  
20

According to the second embodiment, the virtual visual point image PP\_1 shows, on a single screen, a rear scene in a wide visual field, thus improving the visibility in the rear direction of the vehicle 1. In normal travelling or high-  
25 speed travelling, the virtual visual point may be set at the



front of or slightly above the front window **Front\_w**. In such a case, the rear scene of the vehicle viewed from a visual point different from the room mirror and the side mirrors, can be displayed in a wide range, facilitating to make sure of succeeding vehicles and the like.

(Third Embodiment)

According to a third embodiment, it is supposed that the display mode of the vehicle outside display apparatus 10 shown in Fig. 1 is set to a rear surrounding ground display mode. In this embodiment, the two cameras **C1**, **C2** shown in the second embodiment are used as they are. The display mode of the vehicle outside display apparatus 10 can be switched from the rear wide visual field scene display mode to the rear surrounding ground display mode, and vice versa. Such switching can be made manually or automatically.

According to the third embodiment, the cameras **C1**, **C2** are set such that each of the ranges to be captured by the cameras **C1**, **C2** includes an area occupied at the time when the vehicle 1 is retreated at an optional wheel angle by a predetermined distance. Generally, this predetermined distance is preferably set to at least  $N1/N2$  of the vehicle length ( $N1$  is an integer not less than 2,  $N2$  is an integer not less than 3, and  $N1 < N2$ ). From the result of repeated tests conducted by the Inventor, it is found that when the predetermined dis-

tance is set to at least 3 m or 2/3 of the vehicle length, the driver can comfortably execute a backing operation for parallel parking, putting into a garage, tandem parking or the like.

5 Likewise Fig. 16(a) and Fig. 16(b), Fig. 18(a) and Fig. 18(b) show the images TP1, TP2 captured by cameras C1, C2. There are also shown clipping ranges RGN\_03, RGN\_04 according to the third embodiment.

Fig. 19 shows a virtual visual point image PP\_2 displayed on the display 12. According to the third embodiment, the image processing device 11 executes simultaneously a processing of preparing partial images by clipping the captured images TP1, TP2 while referring to the conversion table TBL2 (table for the rear surrounding ground display), a processing of deforming the partial images to the virtual visual point image PP\_2, and a processing of synthesizing the partial images (including a boundary processing). Accordingly, the virtual visual point image PP\_2 as shown in Fig. 19 is displayed on the display 12. In Fig. 19, a vehicle figure M is displayed at the center of the display 12.

When the ranges to be captured by the two cameras C1, C2 are too narrow to sufficiently display, on the screen, the ground around the rear of the vehicle 1, another camera C3 may be added such that the total three cameras C1, C2, C3 are disposed at the rear of the vehicle 1 as shown in Fig. 20(a).

Shown in Fig. 20(a) are the ranges to be captured RC1, RC2, RC3 of the cameras C1, C2, C3. By the addition of a camera, the range of the surrounding ground to be displayed can be enlarged. In such a case, too, it is preferable to dispose  
5 the cameras C1, C2, C3 such that each of the gaps among the image forming points thereof is not greater than 20 cm as shown in Fig. 20(b).

According to the third embodiment, the virtual visual point is present at an upper part of the vehicle. Therefore,  
10 the display 12 displays the virtual visual point image PP\_2 in which the vehicle 1 and the surrounding ground behind the vehicle 1 are viewed from above. Accordingly, the driver can accurately grasp the distance between the vehicle 1 and an obstacle behind the same.

15  
(Fourth Embodiment)

According to a fourth embodiment, it is supposed that the display mode of the vehicle outside display apparatus 10  
20 shown in Fig. 1 is set to a lateral-side surrounding ground display mode.

Fig. 21 is a plan view of a vehicle 1 and its surrounding. As shown in Fig. 21, four cameras C4 ~ C7 are disposed on the roof 14 of the vehicle 1. The cameras C4 ~ C7 are disposed at positions within 20 cm from the end edges of the  
25 roof 14 at the rear left position, the rear right position,

the front right position and the front left position, respectively. The cameras C4, C5 are turned obliquely backward, while the cameras C6, C7 are turned obliquely forward. Shown in Fig. 21 are ranges RC4 ~ RC7 to be captured by the cameras C4 ~ C7 respectively, and white lines 3A, 3B, 3C, 3D drawn on the ground.

Fig. 22(a) to Fig. 22(d) respectively show the images TP4 ~ TP7 respectively captured by the cameras C4 ~ C7. There are also shown clipping ranges RGN\_05, RGN\_06, RGN\_07, RGN\_08 of the captured images TP4 ~ TP7 of the cameras C4 ~ C7. As shown in Fig. 22, each of the captured images TP4 ~ TP7 includes any of the four corners of the vehicle 1.

The captured image TP4 shown in Fig. 22(a) includes the trunk Tr, a rear window Rear\_w, and a left side window L\_w. The captured image TP5 shown in Fig. 22(b) includes the trunk Tr, a rear window Rear\_w, and a right side window R\_w. The captured image TP6 shown in Fig. 22(c) includes the bonnet Bn, a front window Front\_w, and a right side window R\_w. The captured image TP7 shown in Fig. 22(d) includes the bonnet Bn, a front window Front\_w, and a left side window L\_w.

According to the fourth embodiment, the cameras C4 ~ C7 are disposed at a high position of the vehicle 1, i.e., on the roof 14. This reduces cubic distortion of other vehicle, a pedestrian, a structure and the like around the vehicle 1 which are displayed on the display 12. Further, the instal-

lation of the cameras C4 ~ C7 in the vicinity of the end edges of the roof 14, reduces the blind zones generated by the body of the vehicle 1, enabling the surrounding ground to be displayed on the display 12 in a wider range. Wherein, 5 the cameras C4 ~ C7 may be disposed at a roof pillar.

According to the fourth embodiment, too, the image processing device 11 shown in Fig. 1 executes simultaneously a processing of preparing partial images by clipping the captured images TP4 ~ TP7 while referring to the conversion table 10 TBL3 (table for a lateral-side surrounding ground display), a processing of deforming the partial images to a virtual visual point image, and a processing of synthesizing the partial images (including a boundary processing). Accordingly, a virtual visual point image PP\_3 as shown in Fig. 23 15 is displayed on the display 12. In Fig. 23, a vehicle figure M is displayed at the center of the display 12.

In Fig. 23, blind zones D are formed at both lateral sides of the vehicle 1. The blind zone D at the left side can be eliminated by extending the field of views of the forwardly turned camera C7 and the rearwardly turned camera C4 20 such that the visual fields thereof overlap each other. The blind zone D at the right side can be eliminated by extending the field of views of the forwardly turned camera C6 and the rearwardly turned camera C5 such that the visual fields 25 thereof overlap each other. Further, the blind zones can

also be eliminated by combining this embodiment with a fifth embodiment to be discussed later.

(Fifth Embodiment)

5       According to a fifth embodiment, the capturing means is disposed in the vicinity of the centers of the lateral sides of the vehicle such that the blind zone areas for example shown in the fourth embodiment are included in the range to be captured. According to the fifth embodiment, the display mode of the vehicle outside display apparatus 10 shown in Fig. 1 is set to a lateral-side surrounding ground display assisting mode.

10       Fig. 24 is a plan view illustrating a vehicle 1 and its surrounding. As shown in Fig. 24, cameras C8, C9 are disposed at the non-movable part of a left door mirror 15A of the vehicle 1, and cameras C10, C11 are disposed at the non-movable part of a right door mirror 15B of the vehicle 1. Also shown in Fig. 24 are ranges RC8, RC9, RC10, RC11 to be captured by the cameras C8 - C11, respectively, and white lines 3A, 3B, 3C, 3D drawn on the ground surface.

15       Fig. 25(a) to Fig. 25(d) respectively show the images TP8 - TP11 captured by the cameras C8 - C11. There are also shown clipping ranges RGN\_09, RGN\_10, RGN\_11, RGN\_12 of the captured images TP8 - TP11.

25       The captured image TP8 shown in Fig. 25(a) includes the

left side window L\_w and the left side door knob L\_dnb. The captured image TP9 shown in Fig. 25(b) includes the left front winker L\_wn and the left front tire L\_t. The captured image TP10 shown in Fig. 25(c) includes the right side window R\_w and the right side door knob R\_dnb. The captured image TP11 shown in Fig. 25(d) includes the right front winker R\_wn and the right front tire R\_t. In Fig. 25(a) - Fig. 25(d), blind zones DC4, DC7, DC5, DC6 of the cameras C4, C7, C5, C6 shown in the third embodiment, are shown by hatched lines.

According to the fifth embodiment, the cameras C8 ~ C11 are disposed in the vicinity of the door mirrors 15A, 15B at the vehicle lateral sides, enabling the blind zones to be considerably reduced. In this connection, by combining the fifth embodiment with the fourth embodiment above-mentioned, the places which should be seen by the driver to make sure of the safety, are substantially securely included in any of the captured images TP4 ~ TP11 of the cameras C4 ~ C11. As a result, there can be provided a vehicle outside display apparatus excellent in safety. For example, out of the captured images TP4 ~ TP7 of the cameras C4 ~ C7 shown in the fourth embodiment and the captured images TP8 ~ TP11 of the cameras C8 ~ C11 shown in the fifth embodiment, the partial images in the predetermined ranges are clipped to form a virtual visual point image covering the entire range of the vehicle surrounding.

According to the fifth embodiment, too, the image processing device 11 shown in Fig. 1 executes simultaneously a processing of preparing partial images by clipping the captured images TP8 ~ TP11, a processing of deforming the partial images to a virtual visual point image and a processing of synthesizing the partial images (including a boundary processing). Accordingly, a virtual visual point image PP\_4 as shown in Fig. 26 is displayed on the display 12. In Fig. 26, a vehicle figure M is displayed at the center of the display 12.

According to the fifth embodiment, there is prepared a single virtual visual point. Accordingly, there are prepared, on the same virtual visual point, both the images obtained from the cameras C8, C9 shown at the left side of the vehicle figure M and the images obtained from the cameras C10, C11 shown at the right side of the vehicle figure M. However, a plurality of virtual visual points may be set, and the image at the left side of the vehicle figure M may be prepared based on a virtual visual point set immediately above the cameras C8, C9, while the image at the right side of the vehicle figure M may be prepared based on a virtual visual point set immediately above the cameras C10, C11.

The cameras C8 ~ C11 may be disposed, instead of at the non-movable parts of the door mirrors, at the lateral sides of the vehicle, the window visors, the door knob mounting



portions, or the like. In such an arrangement, too, there are produced effects similar to those of the fifth embodiment.

(Sixth Embodiment)

5 Fig. 27(a) and Fig. 27(b) show an example of how the camera is mounted according to a sixth embodiment. Shown in Fig. 27(a) and Fig. 27(b) are a camera 31, a halogen lamp 32 serving as illumination means, and an openable member 33. The camera 31 is retractably disposed, and the openable member 33 forms a part of the vehicle body when closed.

10 When not used, the camera 31 is in a housed state as shown in Fig. 27(a). On the other hand, for using the camera 31, the openable member 33 is opened, causing the camera 31 to be ejected to the outside of the vehicle as shown in Fig. 15 27(b).

More specifically, this sixth embodiment adopts the retractable mode to enable the camera to be ejected and housed. Accordingly, with the camera housed, the vehicle is neither lowered in aerodynamic characteristics nor injured in the 20 beauty of vehicle design. On the other hand, the camera can be protected against dust and water drops.

Instead of the retractable mode, the camera may be installed together with an openable member such as a shutter or the like disposed at the front in the capturing direction.

25 In such a case, the camera is disposed as always housed in

the vehicle body. The openable member may be adjusted such that the member is opened for using the camera and closed when the camera is not used.

Fig. 28(a) to Fig. 28(e) are views illustrating openable cameras 41 disposed at rear wings 42. Fig. 28(a) shows the appearance of the whole body including the vehicle, Fig. 28(b) and Fig. 28(c) show the arrangement for protecting the camera by a door-type openable member, and Fig. 28(d) and Fig. 28(e) show the arrangement for protecting the camera by a slide-type openable member. In the door type, the opening and closing state of a shutter (protective lid) 43 is controlled by a lid opening/closing motor 44 in the same manner as a door is opened and closed (Fig. 28(b) shows the closed state, while Fig. 28(c) shows the opening state). In the slide type, the opening and closing state of a shutter (protective lid) 45 is controlled by a lid opening/closing motor 46 which slides the shutter 45 (Fig. 28(d) shows the closed state, while Fig. 28(e) shows the opening state).

For conveniences' sake, the arrangement using a single camera is illustrated. However, it is a matter of course that a similar opening/closing mechanism can be applied to a twin-camera, too. Here, two types of shutter opening/closing mechanisms have been discussed, but the opening/closing operation may of course be achieved by other mechanism.

The use of such an opening/closing mechanism produces,

in addition to the effect produced by the adoption of a retractable mode, an effect of restraining the camera from being positionally shifted because of no change in camera physical position. In such a case, it is required to dispose

5 the camera at a position which assures the desired visual field. For example, when there is disposed a camera for monitoring the place immediate below and just behind the vehicle, it is preferable to dispose the camera, as turned downward, inside of the rear wing 42 as shown in Fig. 28(a).  
10 This position is not particularly noticeable. Further, the rear wing 42 is already projecting rearward. Accordingly, without the special need to eject the camera for assuring the visual field, the desired visual field can readily be assured. However, when introducing such an opening/closing mechanism,  
15 it is required to design the configurations of the opening/closing mechanism and the shutter such that in the opening state, the camera visual field is not obstructed by the whole or a part of the shutter as opened.

Further, the camera may be disposed as housed in the  
20 vehicle body, and there may be disposed a transparent member such as a glass sheet at the front in the capturing direction.

In Fig. 27, the camera 31 is disposed as corresponding to the halogen lamp 32 for irradiating light to the range to be captured by this camera 31. The camera 31 and the halogen  
25 lamp 32 are made in a unitary structure such that both the

camera 31 and the halogen lamp 32 are ejected and housed at the same time. It is a matter of course that the illumination means may be disposed independently from the camera such that the light is irradiated to the range to be captured by  
5 the camera.

As the capturing means, there may be used a camera having a capturing function of the infrared light detection type. In such a case, the illumination means may be an infrared light source. For example, red light emitting diodes may be  
10 attached to the tail lamp portions, or the tail lamps themselves may be red light emitting diodes. Such an arrangement can improve the visibility of a person, a structure and the like present in the range to be captured even though the surrounding of the vehicle is dark.

15 Provision may be made such that the control of ejecting and housing the camera 31 is automatically made according to the vehicle gear setting, the travelling speed or the like.

For example, when the camera 31 of the sixth embodiment is used as a camera disposed at the rear end of the vehicle  
20 as shown in the third embodiment, the camera 31 may be so arranged, for example, as to be ejected when the vehicle engine is turned on and the gear is set in the backing mode, and as to be housed when the gear is set in other mode than the backing mode.

25 When the camera 31 of the sixth embodiment is used as a

camera disposed as shown in the second embodiment, the camera 31 may be arranged in the following manner. For example, the camera 31 may be ejected when the vehicle under normal travelling continuously travels at a predetermined speed (e.g., 5 50 Km/h) or more for a predetermined period of time or more, and the camera 31 may be housed when the vehicle continuously travels at a predetermined speed (e.g., 30 Km/h) or less for a predetermined period of time or more. It is a matter of course that the camera 31 may be ejected and housed manually.

10 According to the present invention, examples of the vehicle include an ordinary motor vehicle, a light motor car, an automobile truck, a bus and the like. Further, examples of the vehicle may also include a special vehicle such as a crane vehicle, an excavator and the like as far as the technical concept of the present invention can be applied thereto. 15

In the description above-mentioned, the monitoring system according to the present invention is applied to a vehicle, but may similarly be applied to other moving body than a vehicle, such as an air plane, a ship and the like. Further, 20 the camera may be installed on other object than a moving body, such as a shop, a house, a show-room and the like.

Further, the positions and number of a plurality of cameras are not limited to those shown in the embodiments above-mentioned.

## CLAIMS

1. A monitoring system comprising a twin-camera composed of first and second cameras forming a pair,

5 said first and second cameras being disposed such that at least portions of the ranges to be captured thereby overlap each other, and that the optical axes thereof form a predetermined angle of divergence when said optical axes are projected on a camera installation plane parallel to said optical axes,

10 the twist around the optical axis of at least one of said first and second cameras being set such that when an u-v plane of the visual field range of said at least one camera is projected on a reference plane at a right angle to the optical axis of said at least one camera, the u axis is not  
15 parallel to and does not intersect, at a right angle, the intersecting line of said reference plane and said camera installation plane.

20 2. A monitoring system according to Claim 1, wherein said twin-camera is mounted on a vehicle for capturing both the surrounding of said vehicle and a place distant therefrom.

3. A monitoring system according to Claim 2, wherein  
25 said twin-camera is disposed such that said angle of diver-

gence is not less than  $50^{\circ}$  and not greater than  $90^{\circ}$ , and  
that said twist is not less than  $10^{\circ}$  and not greater than  
35° on the assumption that said twist is  $0^{\circ}$  when said u axis  
on said reference plane is parallel to said intersecting line  
5 of said reference plane and said camera installation plane.

4. A monitoring system according to Claim 1, wherein  
each of said first and second cameras has a visual field  
range in the form of a square.

10 5. A method of adjusting a twin-camera composed of a  
pair of cameras mounted on a vehicle for capturing both the  
surrounding of said vehicle and a place distant therefrom,

15 said camera adjusting method being characterized in  
that the tilt, pan and twist around the optical axis of each  
of said pair of cameras, are adjusted using, as indexes, the  
length of a portion, as captured by each camera, of the  
straight line indicating the capturing direction, the length  
of a portion, as captured by each camera, of a straight line  
20 extending along the vehicle end, and the area of the blind  
zone in the capturing direction.

6. A vehicle monitoring system comprising:

a plurality of cameras for capturing the surrounding of  
25 a vehicle; and

an image processing unit for generating, from the images captured by said plurality of cameras, a synthesized image viewed from a virtual view point,

said plurality of cameras comprising a twin-camera composed of two cameras which form a pair and which are disposed in the close vicinity to each other.

7. A vehicle monitoring system according to Claim 6, wherein said twin-camera is mounted in a unitary structure.

8. A vehicle monitoring system comprising:

one or a plurality of cameras for capturing the surrounding of a vehicle; and

an image processing unit for generating, from the images captured by said one or plurality of cameras, a synthesized image viewed from a virtual view point,

at least one of said one or plurality of cameras being mounted on said vehicle at its lateral side, a non-movable part of its door mirror, its window visor or its door knob mounting part.

9. A vehicle monitoring system comprising:

one or a plurality of cameras for capturing the surrounding of a vehicle; and

an image processing unit for generating, from the im-



ages captured by said one or plurality of cameras, a synthesized image viewed from a virtual view point,

at least one of said one or plurality of cameras being disposed as corresponding to illumination means for irradiating light to the range to be captured by said at least one camera.

10. A vehicle monitoring system comprising:

one or a plurality of cameras for capturing the surrounding of a vehicle; and

an image processing unit for generating, from the images captured by said one or plurality of cameras, a synthesized image viewed from a virtual view point,

at least one of said one or plurality of cameras being so retractably mounted on said vehicle as to be ejected when said camera is used, and as to be housed when said camera is not used.

11. A vehicle monitoring system according to Claim 10, wherein said retractable camera is arranged such that its ejecting and housing is controlled according to at least one of the gear setting or travelling speed of said vehicle.

12. A vehicle monitoring system comprising:

one or a plurality of cameras for capturing the sur-

rounding of a vehicle; and

an image processing unit for generating, from the images captured by said one or plurality of cameras, a synthesized image viewed from a virtual view point,

5 at least one of said one or plurality of cameras being mounted on said vehicle together with an openable member disposed at the front in the capturing direction of said at least one camera,

10 said openable member being so controlled as to be opened when said camera is used, and as to be closed when said camera is not used.

# ABSTRACT

To monitor both the surrounding of a vehicle and a place distant therefrom, there is mounted on the vehicle a twin-camera (23) composed of cameras (23L, 23R) forming a pair. To properly set the postures of the cameras (23L, 23R), their tilts, pans and twists around the optical axes are adjusted using, as indexes, the lengths of the portions, as captured by the cameras (23L, 23R), of the vehicle center line (BCL), the lengths of the portions, as captured by the cameras (23L, 23R), of the vehicle rear-end line (BEL), and the areas of the blind zones (S) in the capturing directions.

FIG. 1A

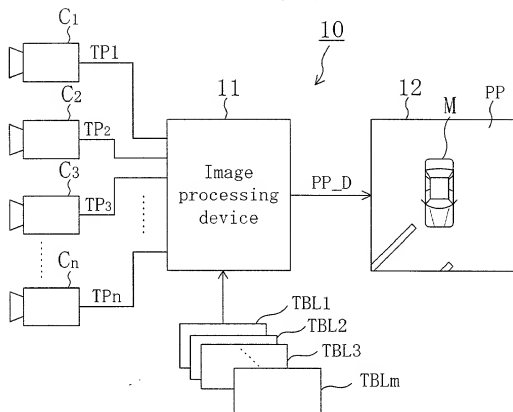


FIG. 1B

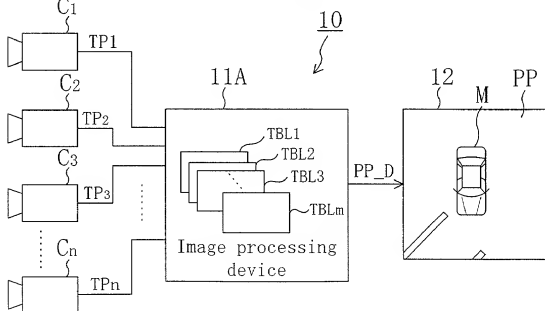
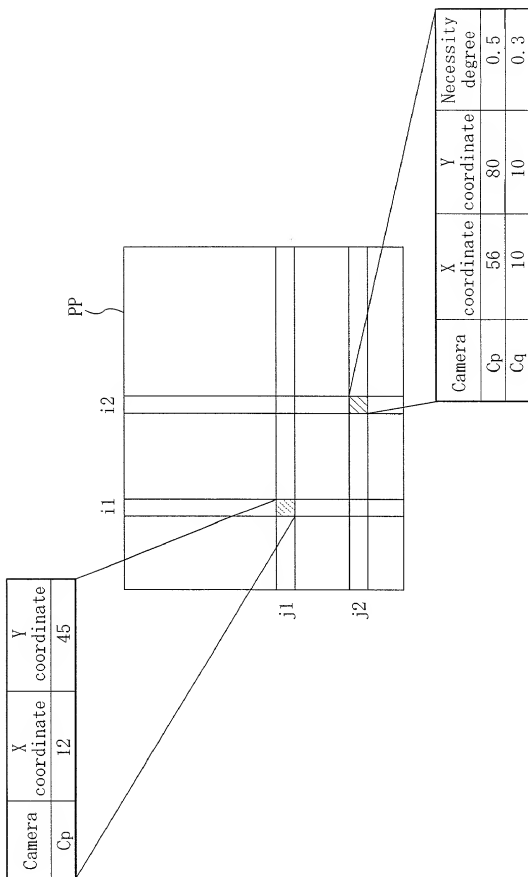


FIG. 2



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FIG. 3

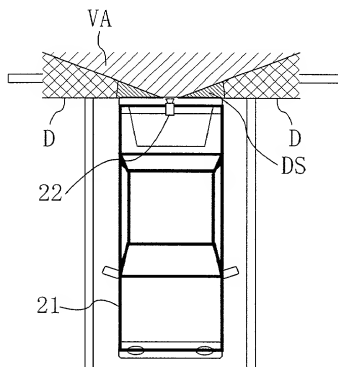


FIG. 4

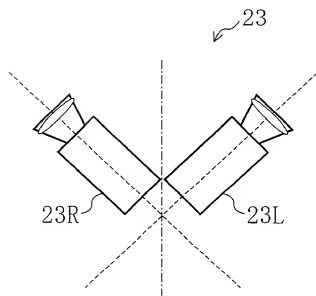
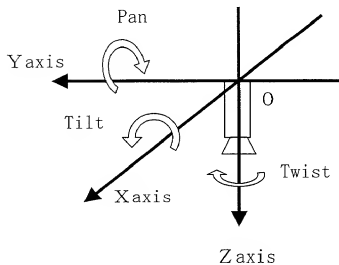


FIG. 5



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FIG. 6A Setting of the tilt  $\otimes$ ...from the front to the inner part

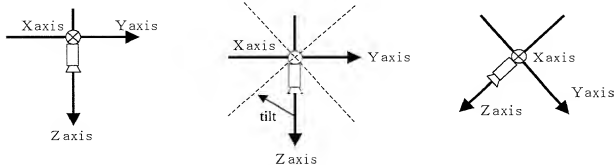


FIG. 6B Setting of the pan of the camera

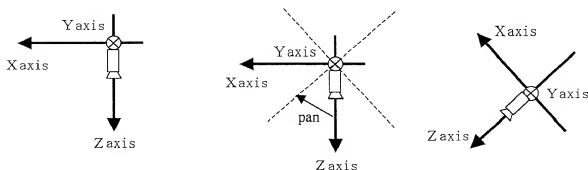
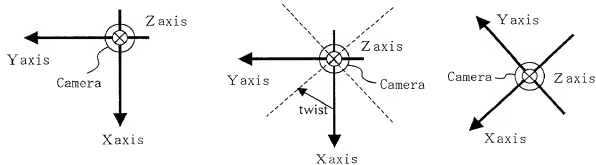


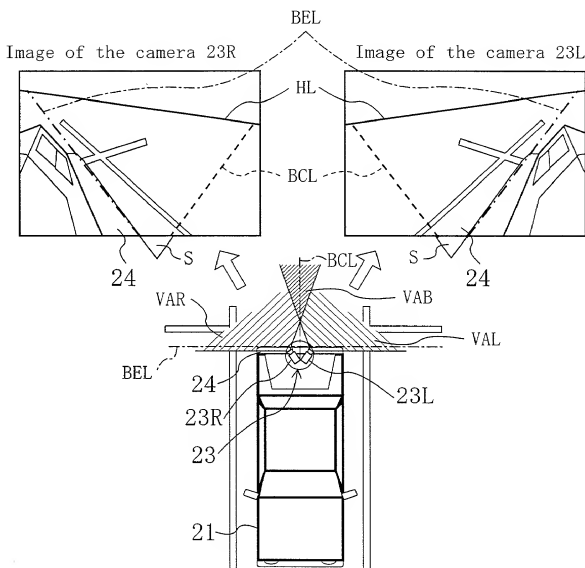
FIG. 6C Setting of the twist around the optical axis of the camera





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FIG. 7



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FIG. 8

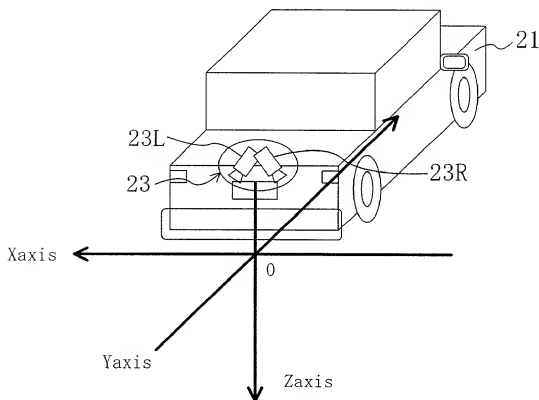
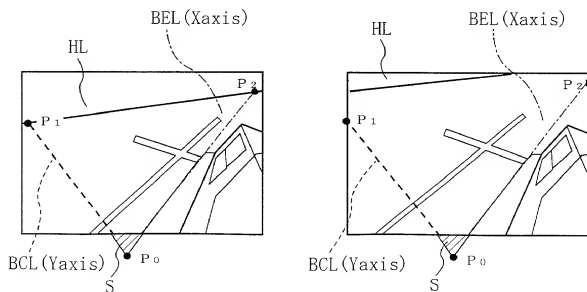


FIG. 9



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FIG. 10A

tilt:  $37.5^{\circ}$

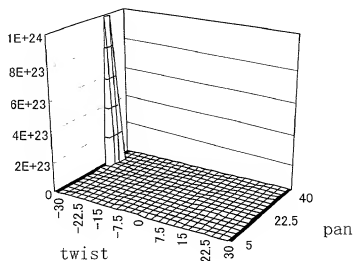


FIG. 10B

tilt:  $42.5^{\circ}$

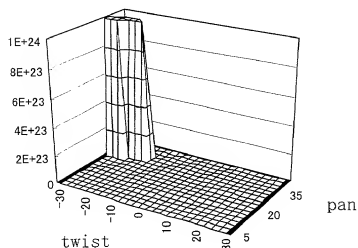
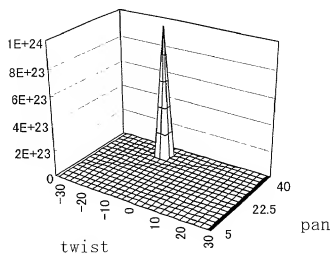


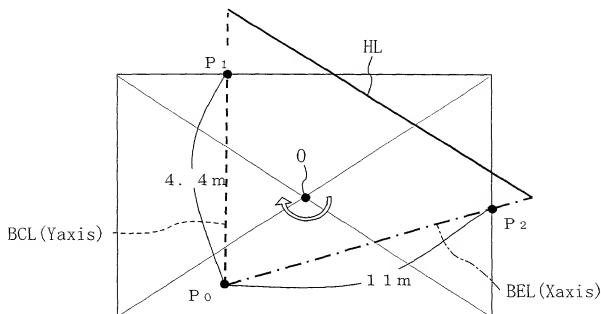
FIG. 10C

tilt:  $47.5^{\circ}$



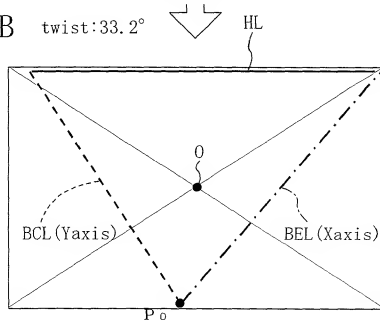
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FIG. 11A twist:0°



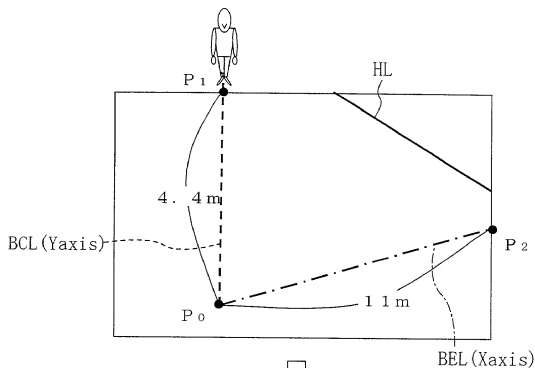
twist:33.2°

FIG. 11B twist:33.2°



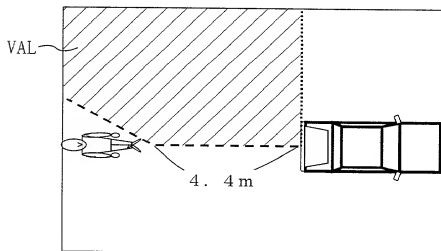
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FIG. 12A twist:0°



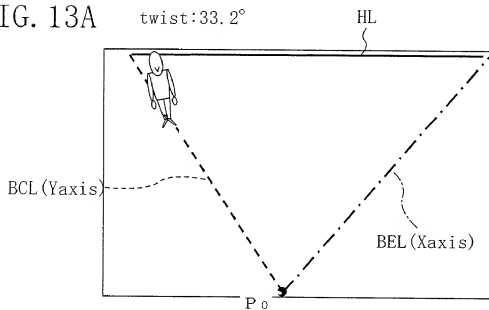
Conversion of the virtual visual point image  
(viewed from above)

FIG. 12B



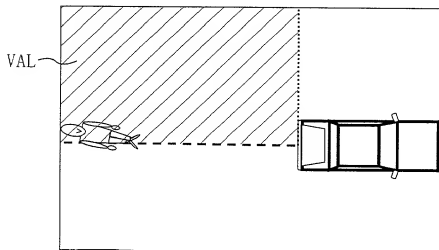
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FIG. 13A



Conversion of the virtual visual point image  
(viewed from above)

FIG. 13B



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FIG. 14A

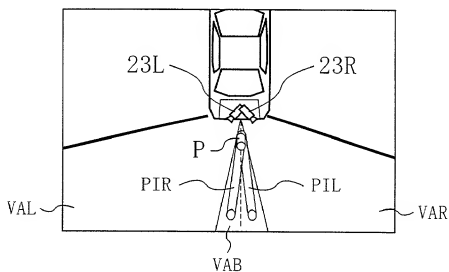


FIG. 14B

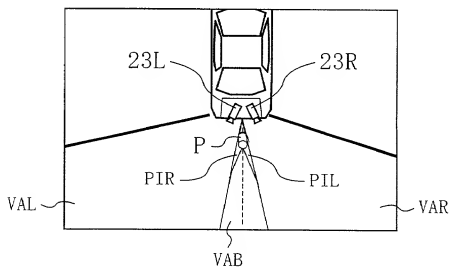


FIG. 15A

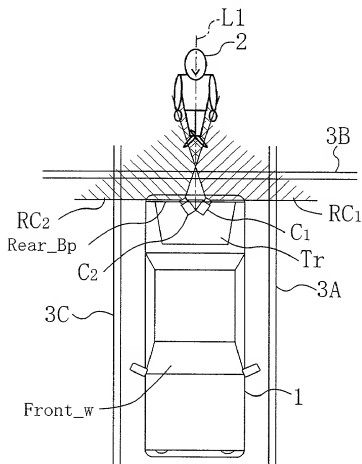
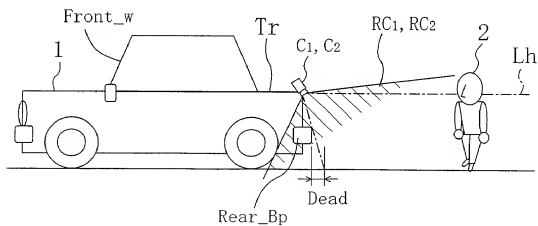


FIG. 15B





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FIG. 16A

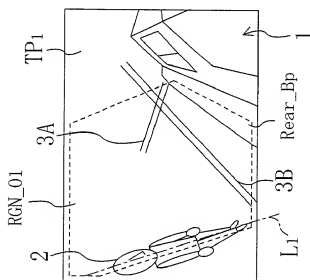
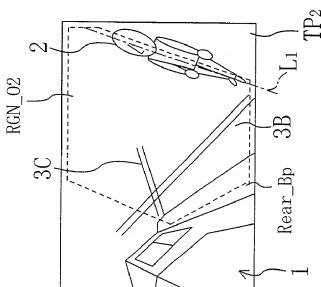
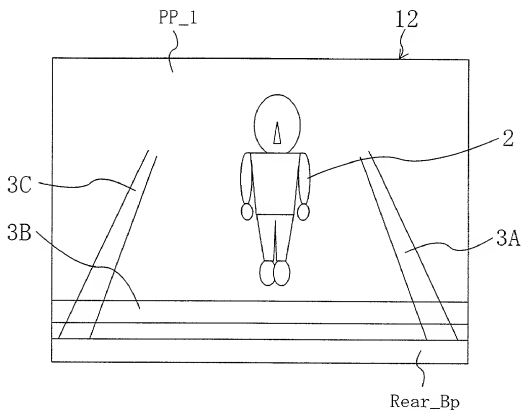


FIG. 16B



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FIG. 17



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FIG. 18A

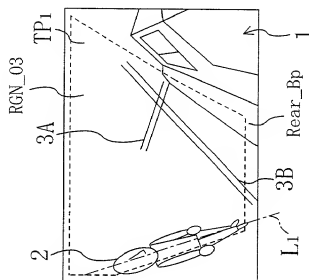
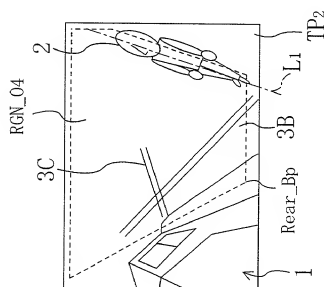
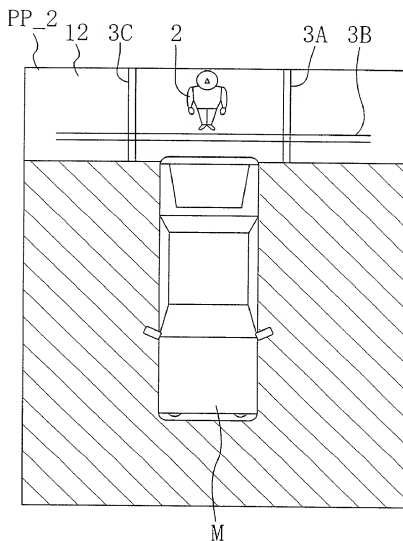


FIG. 18B



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FIG. 19



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FIG. 20A

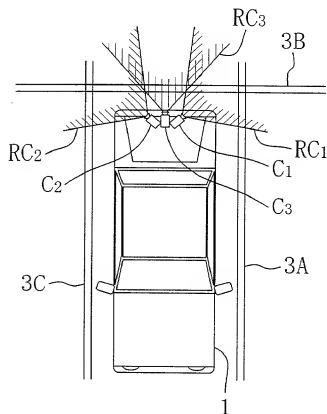
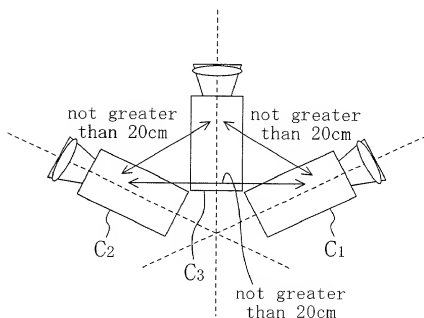


FIG. 20B



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FIG. 21

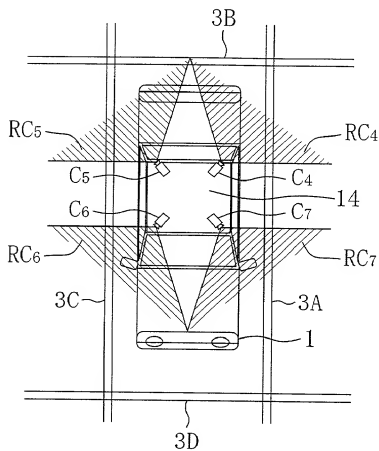


FIG. 22B

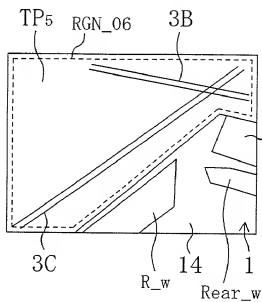


FIG. 22A

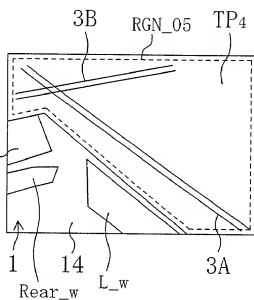


FIG. 22C

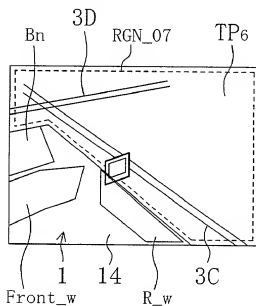


FIG. 22D

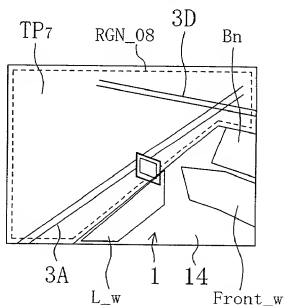
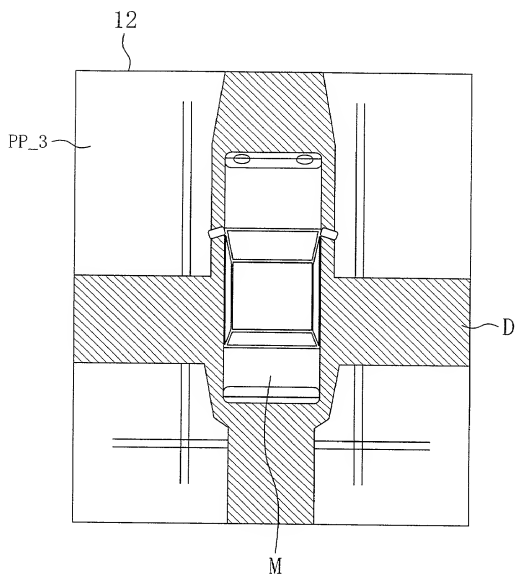


FIG. 23





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FIG. 24

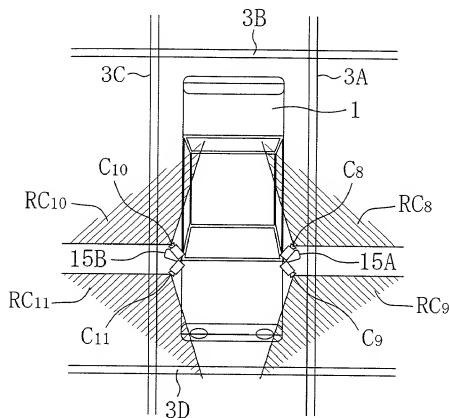


FIG. 25C

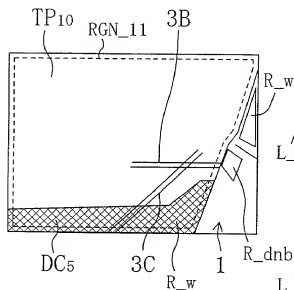


FIG. 25A

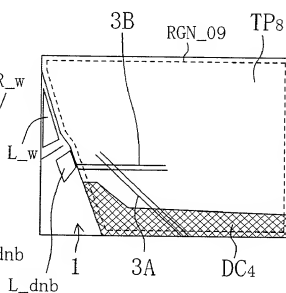


FIG. 25D

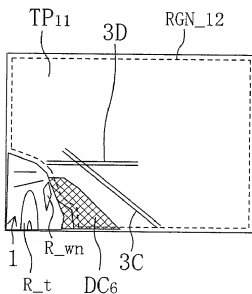


FIG. 25B

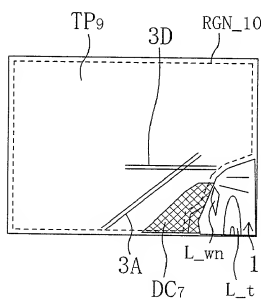
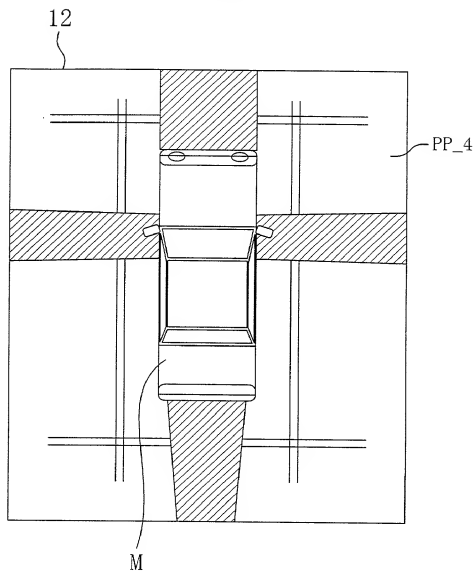


FIG. 26



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FIG. 27A

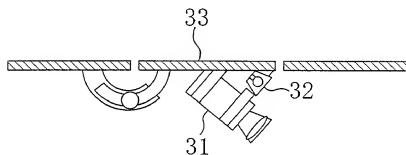


FIG. 27B

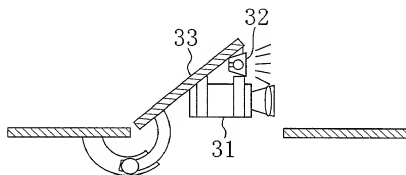


FIG. 28A

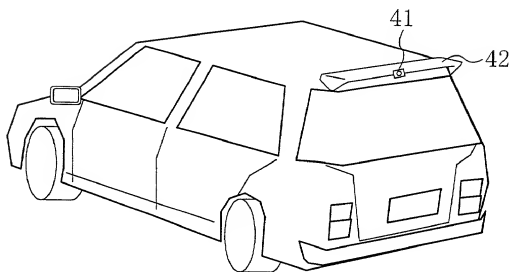


FIG. 28B

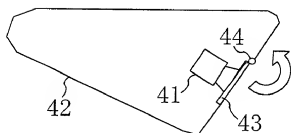


FIG. 28C

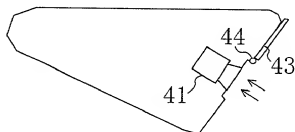


FIG. 28D

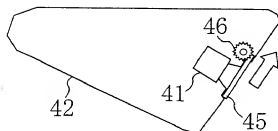
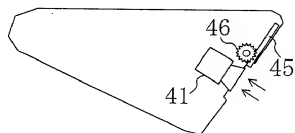


FIG. 28E



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FIG. 29A

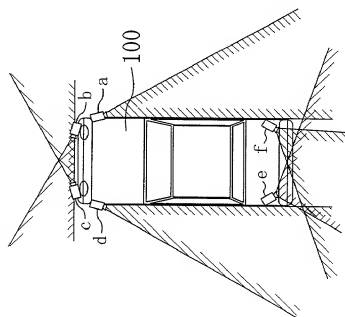


FIG. 29B

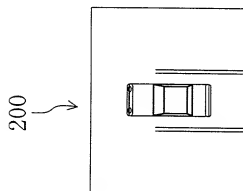
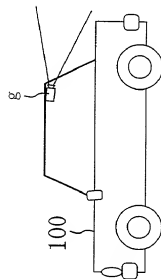


FIG. 29C



**Declaration and Power of Attorney for Patent Application  
(English Language Declaration)**

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

**MONITORING SYSTEM, CAMERA ADJUSTING METHOD AND VEHICLE MONITORING  
SYSTEM**

the specification of which (check one)

☐ is attached hereto.

☒ was filed on **October 12, 2000** as United States Application No. or  
PCT International Application Number **PCT/JP00/07062** and was  
amended on \_\_\_\_\_ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a) - (d) or Section 365(b) of any foreign application(s) for patent or inventor's certificate, or Section 365(a) of any PCT International application which designed at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate or PCT International application having a filing date before that of the application on which priority is claimed.

**Prior Foreign Application(s)**

**Priority Not Claimed**

<u>11-289529</u>	<u>Japan</u>	<u>12/10/1999</u>
(Number)	(Country)	(Day/Month/Year filed)
_____	_____	_____
(Number)	(Country)	(Day/Month/Year filed)
_____	_____	_____
(Number)	(Country)	(Day/Month/Year filed)

I hereby claim the benefit under 35 U.S.C. Section 119(e) of any United States provisional application(s) listed below:

\_\_\_\_\_  
(Application Serial Number)

\_\_\_\_\_  
(Filing Date)

\_\_\_\_\_  
(Application Serial Number)

\_\_\_\_\_  
(Filing Date)

\_\_\_\_\_  
(Application Serial Number)

\_\_\_\_\_  
(Filing Date)

I hereby claim the benefit under 35 U.S.C. Section 120 of any United States application(s), or Section 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. Section 112, I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, C.F.R., Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application:

Application Serial No.	Filing Date	Status – patented, pending, abandoned
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.



POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. *(list name and registration number)*

Customer No. 27572

Harness, Dickey & Pierce, P.L.C.



Send Correspondence to:

Direct Telephone Calls to: *(name and telephone number)*

Gregory A. Stobbs

248-641-1214

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Citizenship: Japanese

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Fourth Inventor's signature:

Date:

Residence:

**Citizenship:**

Post Office Address:

**Full name of fifth joint inventor, if any:**

Fifth Inventor's signature:

Date:

Residence:

**Citizenship:**